Interactive Visualization of Particle Beams for Accelerator Design

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Particle accelerators are playing an increasingly important role in basic and applied sciences such as high energy physics, nuclear physics, materials science, biological science, fusion energy, etc. The design of next-generation accelerators requires high-resolution numerical modeling capability to reduce cost and technological risk and to improve accelerator efficiency, performance, and reliability. While the use of massively parallel supercomputers allows scientists to routinely perform simulation with 100-1000 millions of particles [1], the resulting data typically requires terabytes of storage space and overwhelms traditional data analysis and visualization tools.

The final paper will describe a suite of techniques for visualizing large-scale particle data generated from numerical modeling of beam dynamics. The basis of our techniques is a multiresolution approach. Essentially, coarser representations of the particle data are used so interactive exploration of the data space as well as the visualization parameter space become possible. As soon as a set of desirable visualization parameters are determined, high-quality images of a high-resolution representation of the particle data are made by using a parallel computer.

We will discuss plausible methods for generating multiresolution representations of the particle data. Due to the size of the data, either an out-of-core or a parallel processing approach must be used. We will introduce rendering algorithms specifically designed for particle data, and suggest hardware-accelerated and parallelization strategies for those algorithms. While in the past, visualization of such high resolution data relied on either a batch-mode process or very expensive, high-end multiprocessor graphics engines [2], we are particularly interested in utilizing low-cost commodity graphics cards for the rendering.

The final paper will also addresses another important issue. The high intensity of future accelerator-driven systems places stringent requirements on the allowed beam loss, since very small fractional losses at high energy can produce unacceptably high levels of radioactivity. A major source of beam loss is known to be associated to beam halo [3]. The ability to visualize and better understand properties of particles in beam halo is critical to efficient accelerator design. We are presently investigating a hybrid data representation for the intensive beams and the halo to to facilitate interactive exploration of the beam halo.

The immediate goal of the reported research is to demonstrate interactive visualization with the multiresolution approach. Future work includes studying the time-varying aspect of the data set, and the development of a refined shading model for rendering particles to bring out essential 3D features in the data. This abstract presents some preliminary results from our study of a 100 millions particles data set. All images were generated by first converting the particle data to volume data and then using a single PC with a $300 Nvidia GeForce 3 card which is capable of rendering a 256x256x256 volume at multiple frame per second. Figure 1 shows a cut-away view of the particle density volume. Figure 2 shows a phase space view of the volume. Figure 3 compares rendering of 128x128x128 volume (left) with 256x256x256 volume (right). Finally, Figure 4 contrasts rendering of 128x128x128 volume (top) with 256x256x256 volume (bottom). These images made with a rather crude data mapping scheme demonstrate the value of having a multiresolution representation of the data. By parallel rendering the particle data directly, we believe we will be able to make visualizations at unprecedented accuracy which would give us further insights into the data.

References

[1] J. Qiang, R. Ryne, and S. Habib, "Parallel Object-Oriented Design in Fortran for Beam Dynamics Simulations," Proc. 1999 Particle Accelerator Conf., IEEE Press, Piscataway, N.J., Aug. 1999, pp. 366-368.
[2] P. McCormick, J. Qiang, and R. Ryne, "Visualizing High-Resolution Accelerator Physics", IEEE Computer Graphics and Applications, September/October 1999, pp. 11-13.
[3] J. Qiang, R. Ryne, and S. Habib, "Beam Halo Studies using a 3-Dimensional Particle-Core Model,", Proc. 1999 Particle Accelerator Conf., IEEE Press, Piscataway, N.J., Aug. 1999, pp. 1845-1847.

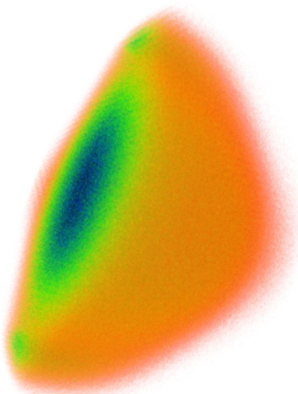

Fig 1. Spatial coordinate view.

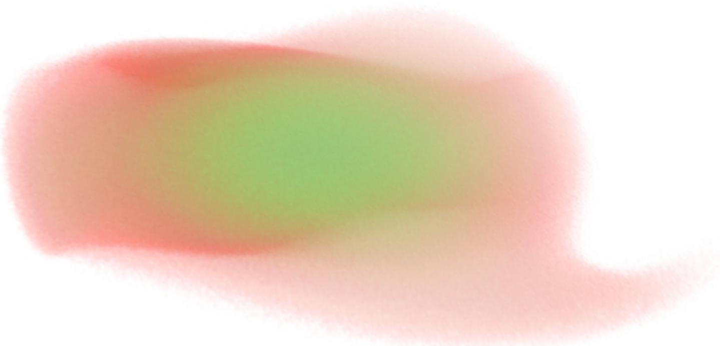

Fig 2. Phase space view.

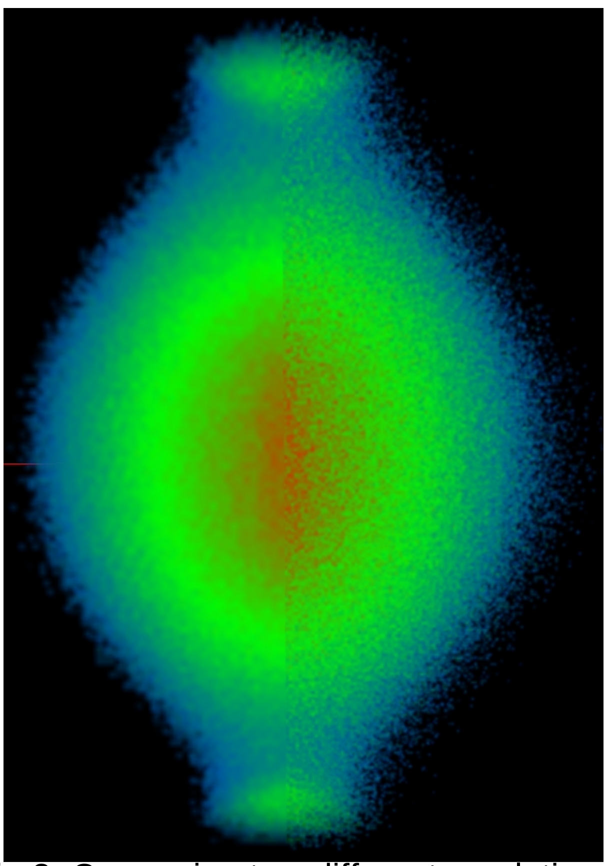

Fig 3. Comparing two different resolutions.

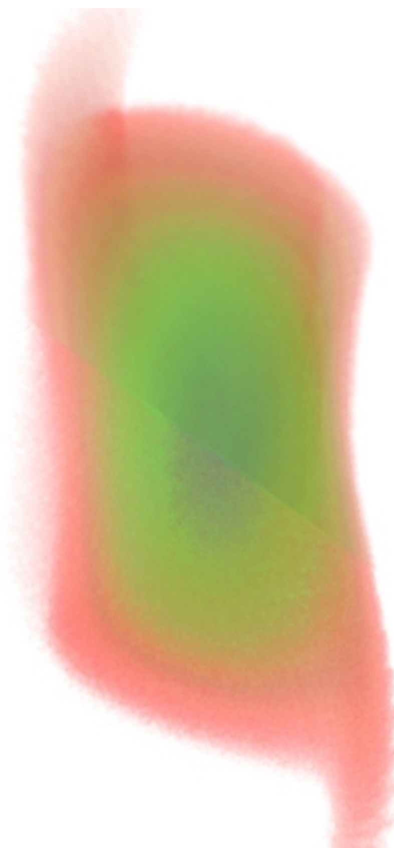

Fig 4. Comparing two different resolutions.